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Indian Standard

METHODS FOR CALIBRATION OF PRESSURIZED STORAGE TANKS

(First Revision)

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METHODS FOR CALIBRATION OF PRESSURIZED STORAGE TANKS

(First Revision)

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Indian Standard

METHODS FOR CALIBRATION OF PRESSURIZED STORAGE TANKS

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 6 September 1976, after the draft finalized by the Petroleum Measurements Sectional Committee had been approved by the Chemical Division Council.

0.2 This standard was first published in 1964. It is being revised in the light of experience gained and data collected. In this revision conditions for recalibration and volume correction factor due to effects of temperature have been dealt in detail.

0.3 The problem of accurate measurement of bulk quantities of liquid petroleum products is not a simple one. Its solution involves accurate engineering and mathematical work, the skill of experienced oil gauger, and the use of carefully standardized and calibrated equipments. Accuracy in measurement is essential in the sale, purchase and handling of oil. It not only obviates possible disputes between the buyer and the seller, but also provides the only reliable means of maintaining adequate control over storage and distribution losses.

0.4 The measurement of bulk quantities of liquid petroleum products involves various processes, such as temperature measurement of oils in tanks, calibration and computation of capacity tables of tanks, gauging of tanks and calculation of bulk quantities of oils in tanks. The need for accurate calibration of tanks cannot, therefore, be overemphasized. The object of this standard is to lay down methods to be adopted uniformly in the country which will enable accurate calibration of pressurized storage tanks.

0.5 In the preparation of this standard due consideration has been given to the prevailing trade practices in the country and to the need for international co-ordination among standards prevailing in different countries of the world in this field. These considerations led the Sectional Committee to base this standard on Petroleum Measurement Manual issued by the Institute of Petroleum (IP), London; and standards and other publications of the American Society for Testing and Materials (ASTM), Philadelphia, USA.

0.6 This standard is one of a series of Indian Standards on methods for calibration of vessels used for bulk storage of liquid petroleum and petroleum products. It covers methods to be adopted for calibration of pressure vessels of the type (a) vertical cylinders, (b) horizontal cylinders (c) spheres, and (d) plain spheroids and noded spheroids.

0.7 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

1. SCOPE

1.1 This standard prescribes methods for calibration and recalibration of the following types of vessels which are normally used for the bulk storage of liquid petroleum and petroleum products under pressure:

a) Vertical tanks,
b) Horizontal tanks,
c) Spherical tanks, and
d) Spheroidal tanks — plain and noded.

2. CONDITIONS FOR MEASUREMENTS

2.1 When drawings for the tank are available, all measurements shall be compared with those obtainable from the drawings and any measurements which show appreciable discrepancies on this comparison greater than the tolerances specified in **8.3.7** shall be verified.

2.2 Measurements shall be taken only after the tank has been filled at least once at its present location with the product to be stored to its maximum working capacity or with water to its equivalent height and such product or water has been held in the tank for at least 24 hours to allow for settling of foundation.

2.3 Liquid calibration is preferred for any tank or portion of a tank not susceptible to adequate or accurate measurement. Similarly when the vessel is visibly distorted, it is best to adopt liquid calibration method.

3. RECALIBRATION AND INTERRUPTED MEASUREMENTS

3.1 The tank shall be recalibrated if:

a) it is repaired or changed in a manner which may affect the total or incremental volumes of the tank,
b) the deadwood is changed or additional deadwood such as concrete is installed inside the tank, and
c) the tank is moved.

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*Rules for rounding off numerical values (*revised*).

3.2 If the calibration of a tank requires to be interrupted, it may be resumed with minimum delay without repetition of work previously completed provided that:

a) any condition laid in **3.1** for recalibration is not violated,

b) there is no change of tank calibrators,

c) all records of work done are complete and legible, and

d) previous level is left undisturbed in case of liquid calibration. In case of fluctuation in level from the previous level as a result of change in liquid temperature, liquid will have to be added or withdrawn to restore the original level.

4. DESCRIPTIVE DATA

4.1 Complete descriptive data should be entered on the tank measurements record form being used.

4.2 Supplemental pencil sketches or notations, each completed, identified, dated and signed will form an important part of field data. These shall be made to indicate typical horizontal and vertical joints; number of plates per course (ring); location of courses (rings) at which thickness of plates changes; location and sizes of pipes and manholes; dents and bulges in shell plates; direction of lean from vertical; method used in by-passing a large obstruction, such as clean-out or insulation box located in the path of a circumferential measurement; location of tape path; location and elevation of datum plate; and all other items of interest and value which will be encountered.

4.3 All measurements made by the tank calibrator shall be recorded on site and not subjected to subsequent correction.

5. ACCURACY

5.1 In order to achieve accuracy in calibration tables, adjustments for effects of the following variables shall be incorporated in the tables:

a) Tilt from upright position, and

b) Tank bottoms that are irregular in shape.

SECTION I CALIBRATION BY STRAPPING

6. GENERAL

6.1 This method is based on the measurement of external circumferences which are subsequently corrected to yield the true internal circumferences.

6.2 The stipulated number of external circumference measurements together with subsidiary measurements, where necessary, to correct for deviation of the tape from the true circular path, shall be obtained as described under strapping procedures for the respective types of tanks.

6.3 Other measurements required to enable a table of capacities to be prepared are:

a) shell thickness;

    1) for the calibration of old tanks, fresh shell thickness measurements should be obtained preferably by non-destructive methods;

    2) for external strapping whenever the shell thickness is taken from drawings or by non-destructive techniques, the paint film thickness as well as the number of coats of paint applied should be recorded in the data sheet;

b) the dimensions of any deadwood, that is, any fitting or object which adds to or subtracts from the capacity of the tank, together with the levels affected.

6.4 It may be necessary in practice to refer all tank dips to a datum point other than the datum point used for the purpose of tank calibration. If so, its position with reference to the original datum point shall be correctly determined.

6.5 A sketch assists in showing what is required, and if the tank shape is in any way abnormal, notes explaining this shall be made, with supporting measurements where necessary. Alternatively, any measurements which give the required dimensions or allow them satisfactorily to be calculated, shall be taken.

7. EQUIPMENT AND TOOLS

7.1 Steel Strapping Tape — shall comply with the requirements given in Appendix A of IS : 2007-1974*. The tape shall be well-greased before use.

7.2 Spring Balance — graduated to show every 0·1 kg from 0 to 10 kg for measuring the tension applied to the tape. For detailed specifications refer to **A-1.2** of IS : 2007-1974*.

7.3 Step-Overs — as described in **A-1.3** of IS : 2007-1974*. This is to correct deviations of the tape from its normal circular path, namely, passing over fittings or joints between plates.

7.4 Dip-Tape and Dip-Weight — complying with the specifications given in **A-1.1** and **A-1.2** of IS : 1518-1960†.

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*Method for calibration of vertical oil storage tanks (*first revision*).

†Method for gauging of petroleum and liquid petroleum products.

7.5 Guide and Chain — a guide sliding freely on the tape, and manipulated by light chains from each side; the guide to be passed around the tank in order to even out the tension in the tape.

7.6 Clamp — to grip the tape, without kinking, at intermediate positions, in order to facilitate application of the necessary tension.

7.7 Steel Rule

8. CIRCUMFERENCE MEASUREMENTS

8.1 Horizontal Tanks — The procedure described in **11** of IS : 2009-1975* shall be followed.

8.2 Vertical Tanks — The procedure described in **11** of IS : 2007-1974† shall be followed. For measurements of dished ends, the procedure described in **14** of IS : 2009-1975* shall be followed.

8.3 Spherical Tanks

8.3.1 A spherical tank is a liquid storage tank in the shape of a sphere generally supported on columns so that the entire tank shell is above ground (*see also* **14.2** of IS : 1518-1960‡). There are usually no internal structural members (*see* Fig. 1A).

8.3.2 Practical difficulties limit tape paths for measuring great circles on the sphere where the tape will lie flat and not tend to slip sidewise. Three representative great circles are chosen — one at the horizontal equator and two passing vertically through the poles at right angles to each other. The total volume is calculated based on these three measurements.

8.3.3 To facilitate the measurement of the horizontal circumference, the builder should tack-weld short rods perpendicular to the shell at the point where the shell is tangent to a vertical line. These may be spaced three metres apart so that the tape may be properly supported at that location.

8.3.4 The columns supporting a sphere may extend above the equator. If the number of supports is 4 or less, then step-overs may be used. A preferred method is to take the circumference measurement at a location just above the top of the columns where the path is clear. When this is done, the vertical distance of the chosen path above the equator should be accurately recorded.

8.3.5 The tank shall be strapped by either of the methods described below. In either case a tension of 4·5 ± 0·5 kg shall be applied to the tape and transmitted throughout its length by suitable means, namely,

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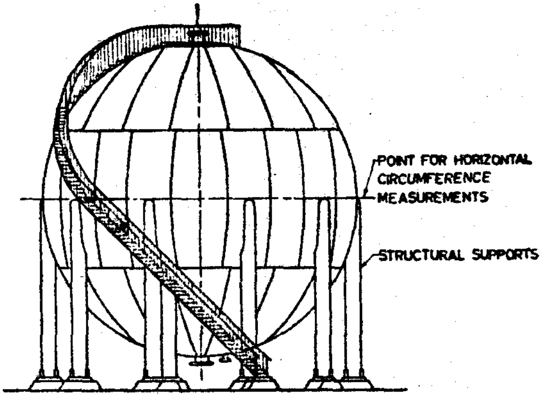
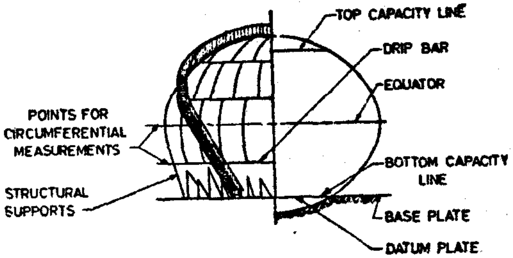
*Method for calibration of horizontal and tilted oil storage tanks (*first revision*).

†Method for calibration of vertical oil storage tanks (*first revision*).

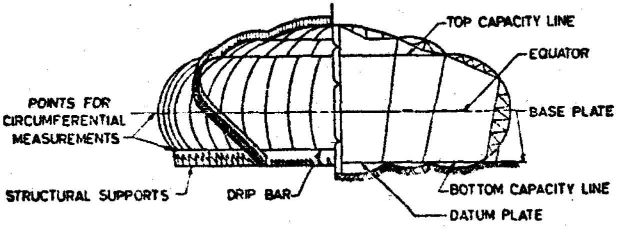
‡Method for gauging of petroleum and liquid petroleum products.



1A Spherical Tank



1B Smooth Spheroidal Tank



1C Noded Spheroidal Tank

FIG. 1 PRESSURIZED STORAGE TANK

a guide sliding on the tape, the guide being passed around with the aid of light chains:

a) If the tape to be used is not long enough to encircle the tank completely, the circumference may be measured in sections. Fine lines shall be scribed on the shell perpendicular to the chosen path and the total circumference is then computed as the sum of the lengths between the scribed lines.

b) If the tape to be used is long enough to encircle the tank completely, then after the tape path has been chosen, the tape is passed around, aligned properly with the help of the guide, proper tension applied and the measurement taken.

8.3.6 All readings shall be repeated by shifting the tape a little around. The final reading shall be the arithmetic average of the two readings.

8.3.7 Measurements shall be read to one millimetre and shall be considered satisfactory if repetition as in **8.3.6** shows agreement within the following tolerances:

Circumference m	*Tolerance* mm
Up to 30	±2
Over 30 to 50	±4
„ 50 „ 70	±6
„ 70 „ 90	±8
„ 90	±10

8.3.8 The total inside height at the vertical centre line of the sphere shall be measured. If the path is obstructed, the vertical inside height shall be measured at convenient distance from the centre line. This distance shall be accurately noted. The height measurement shall be made with a dip weight and tape. Measurements shall be read correct to one millimetre. The reading shall be repeated and shall be within the tolerances given in **8.3.7**. The total inside height (*D*) at the vertical central line of the sphere in case of off-side measurements shall be calculated as follows:

$$D = \sqrt{D_m^2 + 4m^2}$$

where

D_m = inside vertical height in metre at m metre off the centre line, and

m = distance in metre off the centre line.

8.3.9 The instructions given in IS : 2007-1974* for the use of step-overs and dynamometer are wholly applicable.

8.3.10 All items contributing towards deadwood shall be noted down. These items seldom depart from the dimensions given in their detail drawings and hence field measurements are normally not necessary.

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*Method for calibration of vertical oil storage tanks (*first revision*).

8.4 Spheroidal Tanks

8.4.1 A spheroidal tank is a liquid storage tank having a shell of double curvature. Any horizontal cross-section is circular and a vertical cross-section is a series of circular arcs. The height is reduced as compared with that of a sphere. The bottom rests directly on a prepared grade. The spheroidal tank has a base plate resting on the grade and projecting beyond the shell. Structural members rest on the base plate and support the over-hanging part of the shell for a short distance above the plate. A drip bar is welded to the shell in a horizontal circle just above the structural supports to intercept rain-water.

8.4.1.1 A smooth spheroidal tank usually has no inside structural members to support the shell or roof (*see* Fig. 1B).

8.4.1.2 A noded spheroidal tank has abrupt breaks in the vertical curvature called nodes which are supported by a circular girder and structural members inside the tank (*see* Fig. 1C).

8.4.2 Practical difficulties prohibit measuring a spheroid except at two locations. One of these is on the shell at the upper edge of the drip bar and the other at the largest horizontal circumference where the shell is tangent to a vertical line. At other locations it would be difficult, if not impossible, to support the measuring tape.

8.4.3 The strapping procedure remains the same as in the case of spherical tanks.

8.4.4 The elevation of the datum plate relative to the bottom capacity line shall be measured.

8.4.5 The elevation of the top of the drip bar relative to the bottom capacity line shell be measured. The measurements shall be taken at four points equally spaced around the spheroidal tank.

SECTION 2 LIQUID CALIBRATION

9. GENERAL

9.1 Liquid calibration is preferred for any tank or portion of a tank not susceptible to adequate or accurate measurements.

9.2 Liquid calibration is done either by introducing or withdrawing measured volumes of liquid and noting the corresponding change in level.

9.3 Liquid calibration may be performed either by a positive displacement meter or by a proving tank. However, calibration by meter is generally found to be more convenient since the same meter, within its range, can be easily adopted to calibrate different sizes of tanks.

9.4 Procedure given in **2.2** shall be followed before liquid calibration is undertaken.

9.5 Any minor variation in calibrating medium temperature over the calibration period shall be neglected.

9.6 A capacity table should be prepared in any desired increments, preferably 2 cm, using graphs or mathematical methods to establish a smooth curve.

10. EQUIPMENT AND TOOLS

10.1 Dip-Tape and Dip-Weight — as in **7.4**.

10.2 Gauge Glass — equipped with suitable scales.

10.3 Positive Displacement Meter — Preferably equipped with a set stop-valve and calibrated in accordance with the procedure prescribed in IS : 2801-1967*.

10.4 Large Capacity Proving Measures — Each measure shall be accurately calibrated (*see* IS : 2341-1963†). The capacity of the measures shall be adequate for the purpose.

10.5 Pumping System — a suitable pumping system to add or to withdraw water.

11. CALIBRATION BY METER

11.1 The tank may be initially either empty or full. Calibration is done either by introducing or withdrawing liquid. For convenience, it may be preferable to equip the meter with a set stop-valve so that a predetermined quantity can be added or withdrawn. For the differential volume filled or withdrawn the corresponding change in height of the liquid shall be measured by means of a gauging apparatus as prescribed in IS : 1518-1960‡. This volume shall be such that readings are obtained for each 2 cm of the upper and lower 25 percent of the height between the bottom and top capacity lines and for each 4 cm for the intervening height.

12. CALIBRATION BY LARGE CAPACITY PROVING MEASURES

12.1 The tank to be calibrated shall be filled with water to the top capacity line. The water shall then be discharged into the proving measure where it is accurately measured.

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*Accuracy requirements for bulk meters used in petroleum trade.

†Specification for large metric capacity calibrating measures (non-tilting type).

‡Method for gauging of petroleum and liquid petroleum products.

12.1.1 The proving tank shall be not smaller than one half of the largest 2 cm increment of the sphere or spheroid and shall have a maximum capacity of the largest 2 cm increment of the sphere or spheroid. Each proving tank should have been accurately calibrated. For the volume discharged the corresponding change in height of the liquid shall be measured by means of gauging apparatus as prescribed in IS : 1518-1968*.

13. VOLUME CORRECTIONS DUE TO EFFECTS OF TEMPERATURE

13.1 The volume corrections due to the effects of temperature are carried out as follows:

a) The effect of expansion or contraction of tanks containing liquids at normal temperature may be disregarded except under conditions of use requiring extremely accurate results as to the partial or total volumes of heated or refrigerated contents.

b) When corrections for temperature effect are required, it is necessary to estimate the service temperature of the contents and compute volume corrections due to the difference in temperature from 15°C, the normal calibration temperature. The volume corrections can be computed as follows:

   Volume correction percent $= K\ (t_s - 15)$, where K is a coefficient of thermal expansion and t_s is the service temperature of the tank shell in °C.

   The coefficient K is based upon a low carbon steel having a coefficient of thermal expansion of 0·000 011 7 per degree centigrade. When the tank is constructed of a different metal, K shall be calculated in accordance with Appendix A.

c) For non-insulated tanks the temperature of the shell shall be taken as the mean of the adjacent liquid and ambient air temperatures on the inside and outside of the shell at the same location. In applying these principles to both spheres and spheroids only the horizontal dimensions are functions of tank calibration corrections. The liquid height measurement is a function of gauging the liquid level; accordingly the effect of thermal expansion or contraction on innage and outage gauge readings shall be considered separately.

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*Method for gauging of petroleum and liquid petroleum products.

APPENDIX A

[*Clause* 13.1(b)]

PROCEDURE FOR COMPUTING THE VOLUME CORRECTION FOR THERMAL EXPANSION OR CONTRACTION OF SPHERICAL AND SMOOTH SPHEROIDAL TANKS

A-1. DETAILS

A-1.1 The graph (*see* Fig. 2) gives coefficient K^1 based on a mean thermal expansion coefficient, α_m, of 0·000 011 7 per degree centrigrade. The value K^1 taken from the curve shall be adjusted to the actual thermal expansion α_m, of the tank material at the actual tank temperature t. The adjustment shall be done by using the following formula:

$$\text{Corrected coefficient } K = K^1 \frac{\alpha_m}{0\cdot000\,011\,7}$$

where

α_m = the mean coefficient of linear expansion between temperatures t and 15°C (*see* Tables 1 and 2).

After adjusting K^1 for the actual α_m, the corrected value K should be substituted in the equation for volume correction as given in **13.1**(b).

TABLE 1 VALUES OF α_m FOR LOW CARBON STEEL

TANK SHELL TEMPERATURE t °C	VALUE OF α_m PER °C
− 56·5 to − 29·5	0·000 010 80
− 29·0 „ − 2·0	0·000 010 98
− 1·5 „ + 25·5	0·000 011 16
26 „ 53	0·000 011 34
54 „ 80·5	0·000 011 52
81 „ 108	0·000 011 70
109 „ 135·5	0·000 011 88
136 „ 163	0·000 012 06
164 „ 191	0·000 012 24
192 „ 218	0·000 012 42

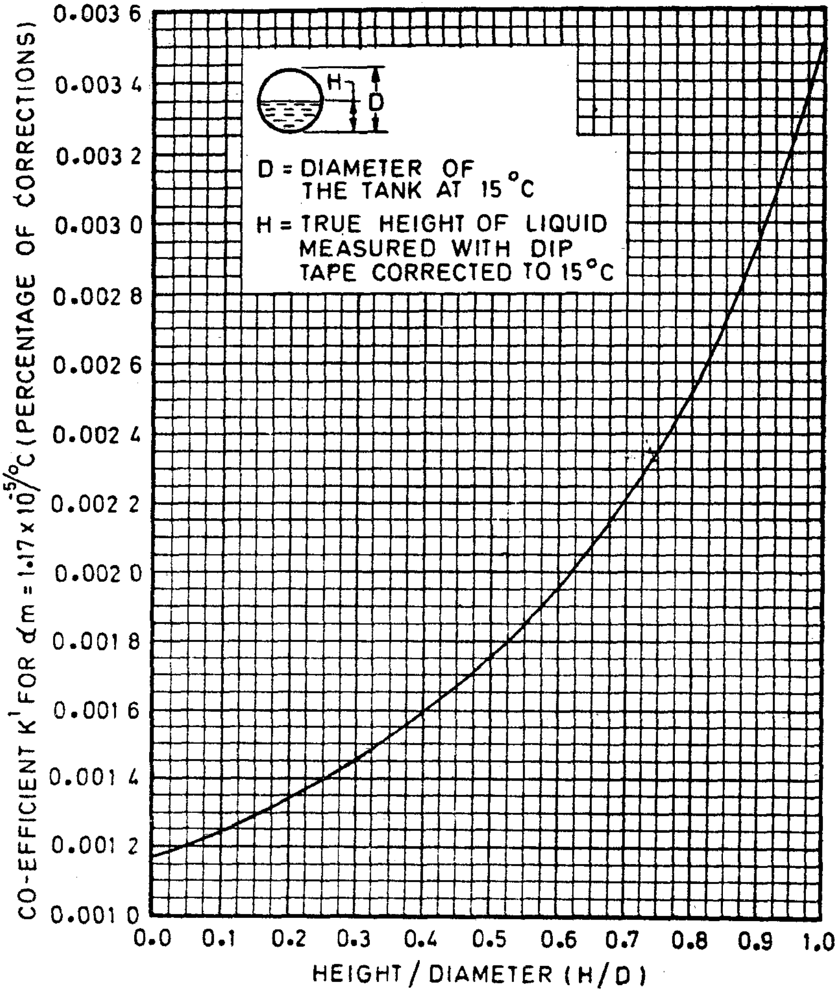

FIG. 2 VOLUME CORRECTION CO-EFFICIENT FOR THERMAL EXPANSION OR CONTRACTION OF SPHERICAL AND SMOOTH SPHEROIDAL TANKS CONSTRUCTED OF LOW CARBON STEEL

TABLE 2 VALUES OF α_m FOR STRUCTURAL ALUMINIUM

(*Clause* A-1.1)

TANK SHELL TEMPERATURE t °C	VALUE OF α_m PER °C
− 56·5 to − 24	0·000 021 96
− 23 „ + 9·5	0·000 022 32
+ 10 „ 43	0·000 022 68
43·5 „ 76	0·000 023 04
77 „ 109	0·000 023 40
110 „ 143	0·000 023 76
143·5 „ 176	0·000 024 12
177 „ 209	0·000 024 48